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WOODS HOLE OCEANOGRAPHIC INSTITUTION

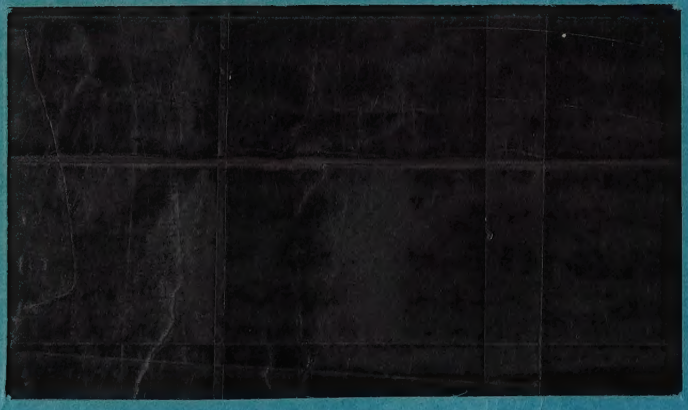
Reference No. 52-80

KETOPHONICS

conducted during the period

April 1, 1952 - September 30, 1952

WOODS HOLE, MASSACHUSETTS



WOODS HOLE OCEANOGRAPHIC INSTITUTION

Woods Hole, Massachusetts

Reference No. 52-80

KETOPHONICS

conducted during the period

April 1, 1952 - September 30, 1952

By

W. E. Schevill
and
B. Lawrence

Periodic Status Report
Submitted to the Office of Naval Research
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October 1952

APPROVED FOR DISTRIBUTION _____
Director

The Contractor shall furnish the necessary personnel and facilities for and, in accordance with any instructions issued by the Scientific Officer or his authorized representative, shall conduct studies in Ketophonics and related acoustic phenomena to include:

(1) examination of the spectrum of whale sounds and the frequency band over which the whale hears;

(2) examination of the mechanisms by which the whale makes sounds; and

(3) the correlation between the whale sounds and other activities of the whale.

REPORT ON KETOPHONICS

The following general summary, in part adapted from papers now being prepared for publication, is submitted as covering the half year from 1 April to 30 September 1952, as well as giving a general background for some of the work.

In the past four or five years our rather general interest in whales has focussed on a few aspects, especially their swimming, their phonation, and their hearing. We have been able to attack these problems only intermittently, but have accumulated a good deal more information and data, which is partly summarized here by way of a preliminary report. Some of it can answer several questions raised in recent publications.

1. As to cetacean swimming, the outstanding contribution is the excellent work of D. A. Parry (1949, Journal of Experimental Biology, 26, 1, May, pp. 24-34, pls. 2-3, and 1949, Proc. Zoological Society (London), 119, 1, May, pp. 49-60). This so impressed us that we put aside our notes prepared just before his papers appeared, and had not contemplated using them until the appearance of L. Harrison Matthews' authoritative book, "British Mammals", in 1952. Here Parry's conclusions are discounted. On the basis of direct observation, motion pictures, and dissection we can confirm Parry's report of the propulsive action of the tail, with its vertical oscillations on two hinge regions. In this way the whale adjusts the stroke to the power requirements by varying both the amplitude and the angle of attack, and so obtains its impressive efficiency. This highly efficient swimming has much to do with the acute hearing of whales; it is suggested that this non-turbulent swimming motion enables the animal to hear well even when under way.

2. As to phonation and hearing, it has for some years been well-known to seagoing people in general and naval men in particular that the smaller whales, at least, responded to sounds and made them over a wide range of frequencies. This has been a commonplace item among those who work with marine acoustics. It should be borne in mind that our distinction between sonic and ultrasonic frequencies is a purely subjective human one, and has no significance for animals with different ranges of hearing. Our own experience has included both standard and experimental equipment, and has confirmed what others have also noticed, that porpoises will often depart from a ship when an echo-sounder or any other intense sound source is turned on. This had been observed for both sonic and ultrasonic frequencies, up to 60 kc.

Similarly, sounds presumably made by cetaceans, as well as by other marine animals, have often been a source of trouble to acousticians. In 1948 (published 1949, Science, 109, 11/II/49,

pp. 143-144) we established definitely that a particular cetacean, Delphinapterus (the beluga) actually made a great variety of underwater sounds, and in 1949 we recorded some of them (published 1950, WHOI Ref. No. 50-1). Since then we have listened to and recorded similar but not identical sounds produced by Tursiops, Globicephala, Stenella, and "Grampidelphis", as well as a few unidentified cetaceans. It may be noted that all those identified as soniferous are odontocetes, or toothed whales, and that so far all our listening to mysticetes, or whalebone whales, (Balaenoptera, Eschrichtius, and Megaptera) has not resulted in our hearing any underwater sound from them. (See Section 4 below).

Our observations at Marine Studios had shown that the porpoise sounds were made without expulsion of air, although one sound (the squeal) was usually accompanied by the release of the string of small bubbles reported by previous observers. Dissections and experiments with the larynx of dead Delphinus and Stenella showed, as will surprise no laryngologist, that the absence of vocal cords is no obstacle to sound production.

One of our objects under this contract is to investigate the possible significance of cetacean phonation as a means of communication. From the beginning we have planned to test this by recording the calls and then playing these back to the same species in order to study the resulting reactions. It seemed clear from the start that this experiment would not have much meaning unless we could play the calls back with reasonable fidelity. Our previous experience had made it clear that these animals had a range of hearing much broader than the broadest of available broad-band systems; a basic requirement for such an experiment is a broad-band system approximating the animal's hearing range.

On the analogy of other animals, including man, we supposed that the frequency range of utterances would exceed the frequency range of hearing, so that we did not feel that measurements of porpoise calls would teach us the limits of their hearing. Nevertheless, we did attempt such a playback experiment in 1951, even though we felt sure our gear was inadequate by at least an octave. With the aid of Magnecord, Inc., of Chicago, who kindly supplied a special recorder, we had arranged a system with good response to 30 kc, broad band. With this we worked in the waters near St. Augustine, Florida, and actually succeeded in attracting wild Tursiops truncatus (bottlenosed porpoise); these experiments were too limited, however, to give definitive answers. The need to know the hearing range of these animals was emphasized. By this time we had determined that this species had a vocal range that reached 100 kc (this was the limit of our listening equipment) and still had a good deal of energy at that point.

Accordingly, we planned a conditioned ~~reflex~~ response test on a Tursiops. As on many other occasions, Marine Studios was most helpful in allowing the fullest use of their facilities. Fearing the uncertain influences of prolonged captivity, we avoided the use of any of the specimens kept in the oceanarium there. Further, we distrusted the acoustic effects in that steel cylinder, 75 feet in diameter and 12 feet deep, with its complex background noises. Moreover, the difficulties of assessing responses among a crowd of a dozen active porpoises seemed unnecessarily large. Therefore we requested a fresh-caught wild adult Tursiops, which was installed in a separate enclosure (a fenced-off muddy inlet on the Marine Studios grounds). Although it is customary in psychoacoustic tests of this sort to make measurements of a large series of subject animals, we felt that at this stage of ketophonics a reconnaissance investigation of even one individual would be informative. This test was carried out in May and June 1952, with active support from Dr. J. B. Hersey's acoustics group at WHOI; Mr. M. E. Edwards served as field technician. As before, we are grateful to Marine Studios for hospitality and active help, especially Messrs. W. F. Rolleston, F. G. Wood, Jr., and Frank Essapian.

Our emphasis in this work was on the upper limit of hearing, as it is this that most concerns us in the design of a broad-band acoustic system; this point of view influenced the selection of our equipment. It is obvious that such a broad-band system will be difficult, if not impossible to achieve, and that some compromise with simplicity may be required. The ONR Underwater Sound Reference Laboratory at Orlando was most helpful, supplying the sound projectors and much of the associated equipment. We used three, a 1 K, a 6 b, and a 5 A, and projected tones from 150 to 155,000 cps produced by a commercial oscillator. Our monitoring system consisted of an AX 58 hydrophone used with a WHOI-designed sound level meter ("Suitcase") for frequencies below 50 kc, and an AX 40 hydrophone with an HRO tuning receiver and electronic voltmeter from 50 to 200 kc. The porpoise was conditioned to come to us and receive a fish from the hand whenever it heard our signal. Preliminary study of the data indicates that our Tursiops truncatus (bottlenosed porpoise), an adult female, surpassed by about an octave the 60 kc point that had been the highest we knew of; her 50% response (the frequency below which she responded more than half the time and above which she responded less than half the time) was near 125 kc. Details will be reported later, together with explanations of how the responses were assessed. During the tests, the porpoise herself was often heard "talking" at all frequencies used in the experiments, that is, up to 155 kc. At the conclusion of this work, the monitoring system was used in the large circular oceanarium, where the exhibit of Tursiops

and Stenella was; the approximate upper limit of their sound production is still uncertain, for some of their calls were still noticeable (8 to 10 db above background) at 196 kc, the effective upper limit of our equipment.

3. Echo-location (echo-ranging). As far as we know, practically everyone who has thought about underwater sound production and hearing by cetaceans has suggested that the animals probably make use of echo-ranging. We are no exception in this, but we have preferred not to talk about it as unsupported by observational evidence. However, since we are often asked about it, and since, as a suggestion, it has lately appeared in print (Kellogg, W. N., and R. Kohler, 1952, Science, 116, 5/IX/52, pp. 250-252), it may be well to explain our reluctance. Acoustic echo-ranging is practiced by bats and men, and not necessarily with "ultrasonics", although the higher frequencies have the advantage of greater directionality. Cetaceans live in water, through which it is hard to see. Except in daylight in especially clear water, they may be thought of as normally outswimming their visual range, yet they appear to run no serious risk of collision and also catch their food, which is in many cases very active. How do they manage this? We do not know, but we can say that we have sought for and failed to find evidence of echo-ranging.

The evidence we seek is based on an understanding of the technique shared by bats and men. Discrete impulsive sounds are repeated at intervals appropriate to the range of the target (obstacle), and this interval (and thus the pulse rate) is reduced as the range decreases. This method is practiced by men (e.g., echo-sounders with their deep and shoal scales) and has been demonstrated by Griffin and others in bats, which have been doing this much longer.

Although we have heard and recorded impulsive sounds from porpoises (some much resembling sounds made by electronic echo gear), we have failed to detect any such systematic regime as we have just alluded to, and therefore feel that the case for echo-location by cetaceans is not proved. This is not to say that we deny that these animals may not note and utilize echoes that return from such sounds as they do make, perhaps according to some other technique; we just cannot prove it.

4. The "SOFAR moans". In the spring of 1948 the Kaneohe SOFAR station recorded some low-frequency marine sounds which attracted a good deal of attention. There was no clear indication of the source of these sounds, but because humpback whales had been reported in the vicinity during this time, and to some extent also because it was felt that such deep tones must be made by

large animals, there was a widespread tendency to attribute the sounds to these whales. Although this attribution has usually been made more or less tentatively, as by Dr. Martin Johnson on an NEL phonograph record of biological sounds, and by Mr. O. W. Schreiber (in Jour. Acoust. Soc. Amer., 24, 1, p. 116, January 1952), further references, as in newspapers, were usually definite.

These sounds are not peculiar to the Kaneohe foreshore. Much the same sort of disturbance has been heard on the Bermuda SOFAR station, and also at sea well offshore by NEL and WHOI ships in both the North Pacific and North Atlantic.

As mentioned above, we have never succeeded in detecting any sound (other than splashing or blowing at the surface) from any mysticete (whalebone whale), although we have listened carefully to three genera, Balaenoptera (comprising the fin whales), Eschrichtius (the gray whale), and Megaptera (the humpback whale).

The attribution of these loud and widespread sounds to a kind of whale otherwise distinguished for taciturnity seemed to us to call for a check. Accordingly we spent a week off Bermuda in April 1952 on R/V CARYN. At this time the humpback whales pass through the area in great numbers on their annual northerly migration. We had about 25 whale-hours of listening, with the whales, mostly in groups, within 200 yards of the ship, and with additional ones at greater ranges. They were often very near the hydrophone, sometimes within ten feet. Nothing but occasional splashes and blowings were heard from them. We know of no animal that makes sounds (phonates) that does not make them when active, and thus find it difficult to credit the humpback whales with making these "SOFAR moans". But the situation is not this simple. The moans, in the Bermuda area at least, are almost entirely nocturnal, chiefly between about 2100 and 0400. During the hours of darkness we failed to find whales, dependent as we were on visual contact, yet they must still have been in the area. However, it should also be pointed out that the humpbacks had been passing Bermuda for at least a week or ten days before the first moans of the season were detected by either the SOFAR station or by us.

Our conclusions for the time being are:

1. There is no direct evidence that the humpback whales make any sounds whatsoever, even when active and in groups including calves.

2. The source of the impressive moans is still unsettled. It is not even certain whether the sounds are made by mammals or fish or by both (we have never heard any underwater sound from a marine turtle).

3. Our best hypothesis is this: At this season the surface waters warm up, the reef animals become more active, and an unknown number of animals, including fish and whales, come by in poleward migration. In short, it is spring. Among the animals becoming more active are some soniferous ones that contribute to the moans. The chances are that the source or sources of these sounds are deep-sea rather than reef animals. The humpback whales are just one kind among many high-seas migrants. But they are by far the most conspicuous on account of their large size and frisky behavior at the surface. It is thus not surprising, but still unjustified, that they be associated with impressive sounds which roughly coincide with their presence.